

EFFECTS OF COOLING ON PERFORMANCE TIME AND RECOVERY IN INDIVIDUALS WEARING A PROTOTYPE FIREFIGHTER ENSEMBLE

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Introduction

- While providing protection in hazardous environments, firefighting ensembles impose a heavy weight load on the wearer and contribute to the development of uncompensable heat stress due to high clothing insulation and reduced evaporative heat exchange. This phenomenon is further aggravated in hot and humid environments in which physical performance capability is degraded and the risk of heat injuries increases.
- A number of previous investigations have examined effective body cooling methods to reduce thermal stress and to support physical performance in firefighters.
- Liquid cooling garments (LCG), first developed for astronauts, have been shown to be a safe and efficient cooling tool in uncompensable heat stress conditions in some applications.

Purpose

To investigate the effects of body cooling via liquid cooling garment (LCG) on performance time and recovery rate of individuals exercising while wearing a fully equipped prototype firefighter ensemble (PFE).

Methods

Subjects: Six healthy males: 30.5 ± 6.8 years old; height: 182 ± 8 cm; weight: 90.6 ± 12.2 kg; BMI: 27.7 ± 5.32 kg/m²; BSA: 2.11 ± 0.13 m²; VO_{2max} : 46.3 ± 6.6 ml/kg/min; completed 3 sessions of a treadmill exercise protocol in an environmental chamber (35 °C and 50% RH) while wearing PFE and SCBA.

Exercise and cooling protocol: The treadmill exercise protocol consisted of 3 stages of 15 min exercise at 75% VO_{2max} , and 3 stages of 10 min rest following each exercise stage. Each stage of exercise was stopped and proceeded to rest stage if the subjects reached 90% of HR_{max} or were not able to continue exercise. The experimental cooling conditions (randomly assigned) included control (CON; no cooling), top cooling garment (TCG; covering head and forearm), and cooling garment (CG; covering head, torso, forearm, and thigh) (Fig.1), inlet water temperature for TCG and CG were constantly set at 18°C.

Measurements: T_{re} (rectal temperature), T_{sk} (arm, chest, thigh, and calf), HR, and microclimate temperature were recorded throughout the experimental session. Subjective heat sensation and fatigue level were measured at the end of each rest stage. Total performance time (PT) was determined as the sum of exercise duration completed from 3 exercise bouts.

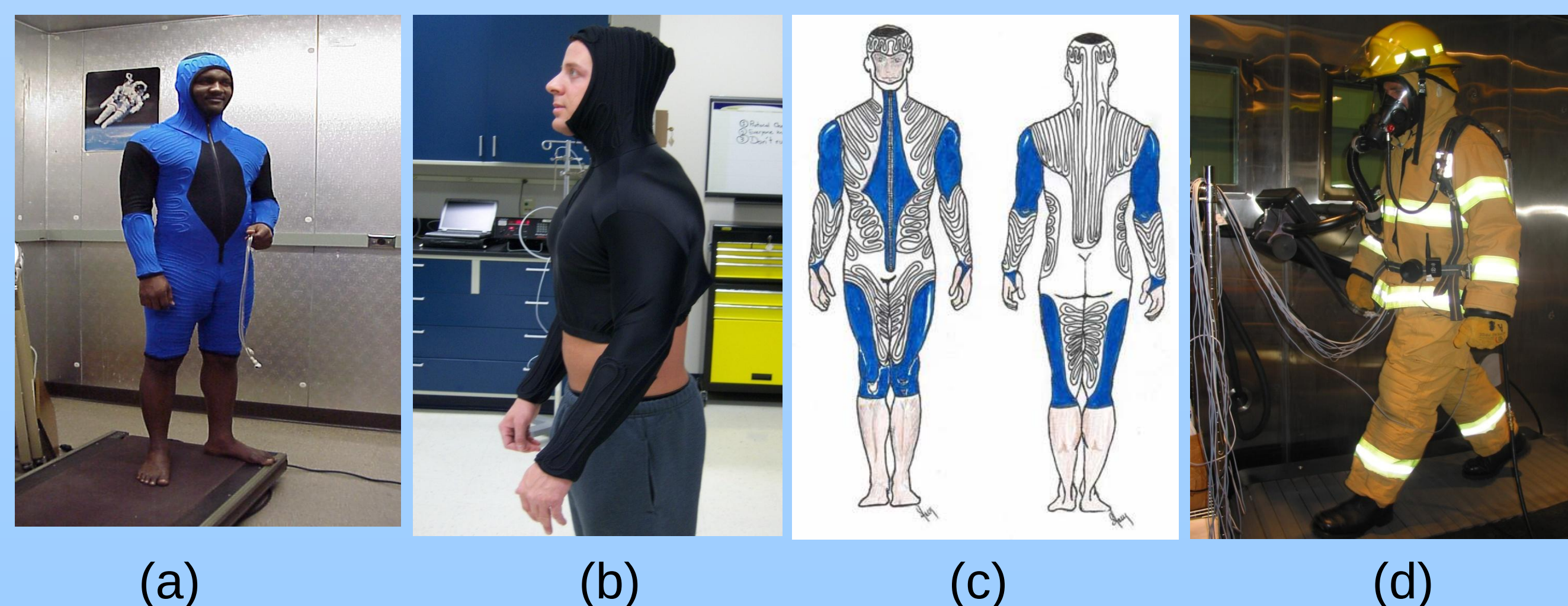


Figure 1. a) CG; b) TCG; c) Schematic of CG tubing distribution; d) Subject in PFE

Statistical analysis: Data were summarized as mean and standard deviation for each subject across conditions or rest stages. Repeated measures ANOVA with post-hoc pairwise comparison was carried out for dependant variables; PT and ΔT_b (conditions); T_{re} , HR, subjective measures (rest stages $\times$ conditions), and microclimate temperature (pre-post $\times$ conditions). An alpha level was set at 0.05.

Results

- PT (min) completed during 3 bouts of exercise was significantly greater in CG (38.3 ± 8.0) than CON (24.8 ± 2.7) and TCG (25.5 ± 4.3).
- The rate of increase in T_b (°C/min) was significantly lesser in CG (0.016) than in CON (0.03) and TCG (0.025).
- No experimental conditions appeared to suppress T_{re} elevation, but a mean absolute elevation during rest stages was found to be significantly lower in CG (0.10 ± 0.04) than TCG (0.21 ± 0.06) and CON (0.28 ± 0.05), (Fig.2).
- Mean HR recovery during rest stages was significantly greater in TCG (-51 ± 11) and CG (-57 ± 6.2) than CON (-41 ± 40), (Fig.2). Also, thermal strain on HR ($\Delta HR_t = HR_{end recovery} - HR_0$) was significantly greater in CON (47.3 ± 9.3) than TCG (38.3 ± 6.7) and CG (25.5 ± 15.2).

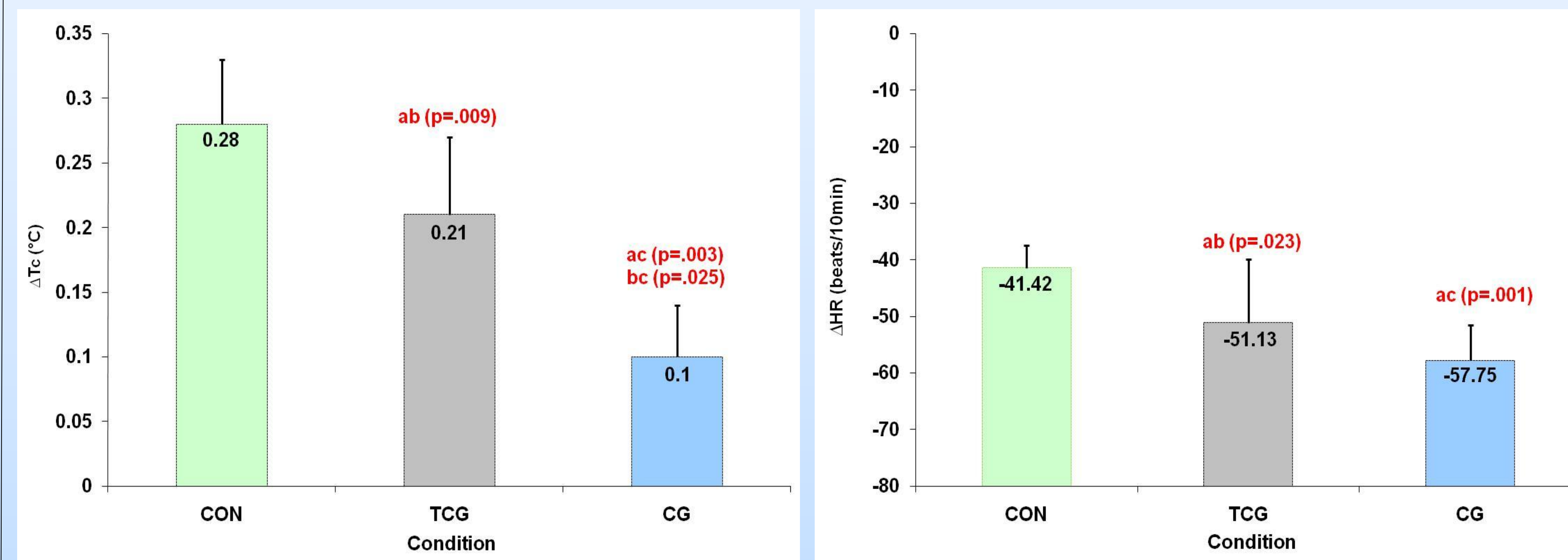


Figure 2. Comparison of mean change in T_{re} (left) and HR (right) during rest (mean of 3 rest stages; 10 min each) . a: CON, b: TCG, c:CG

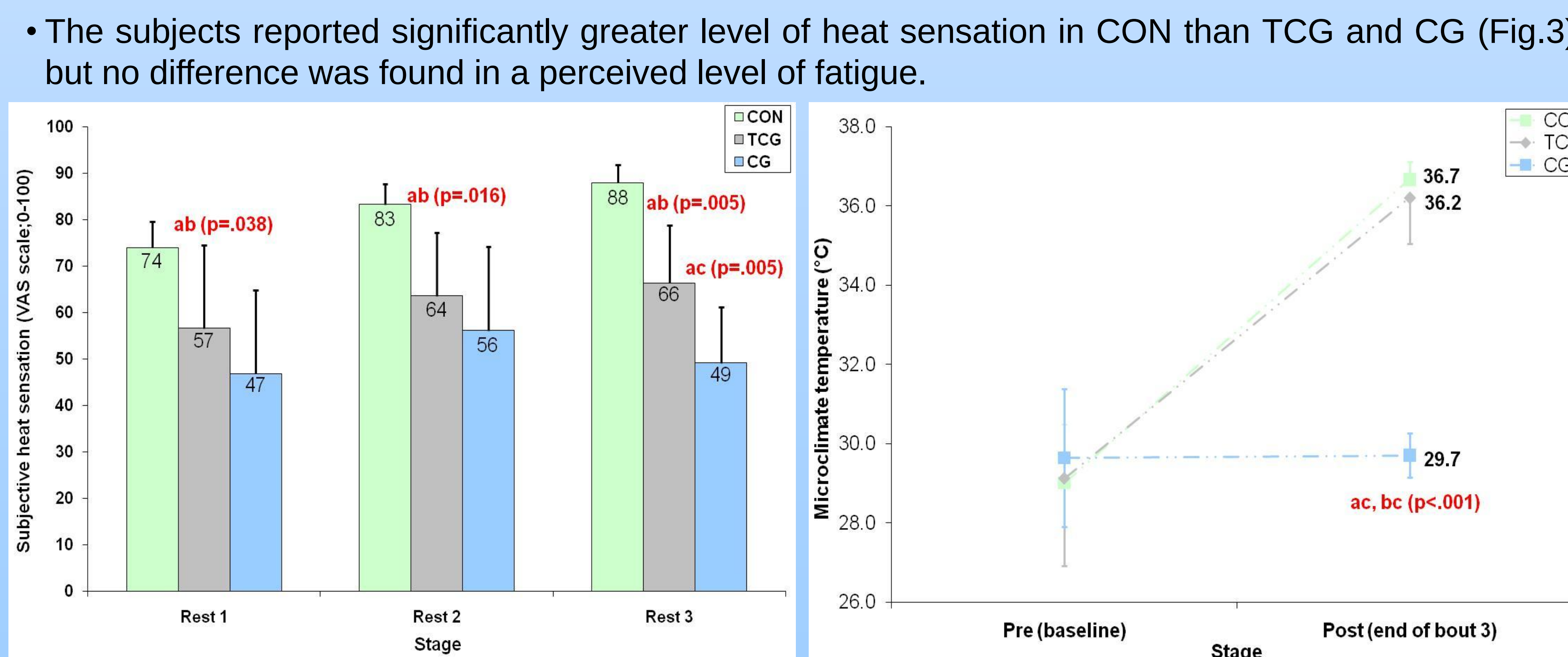
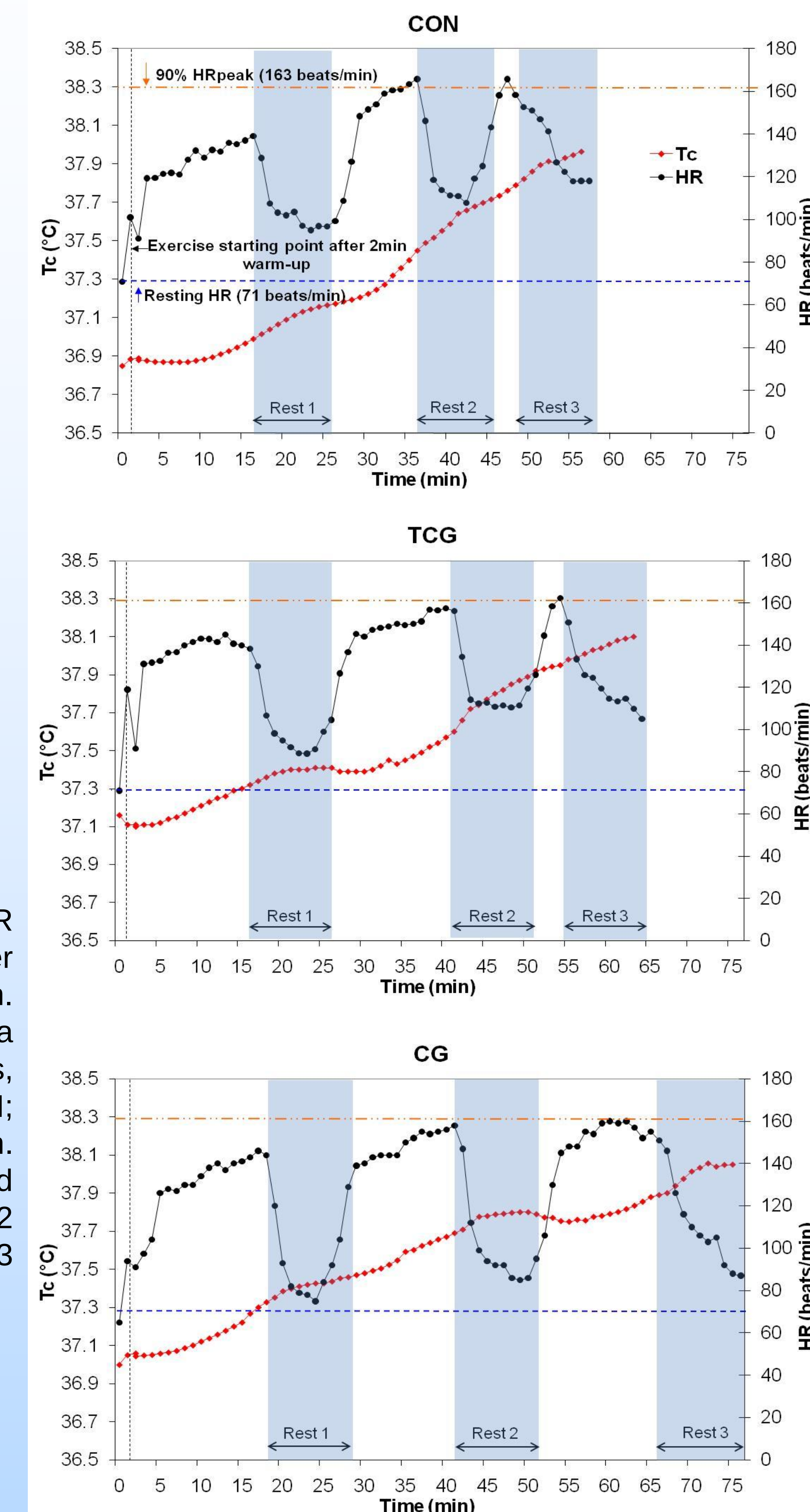


Figure 3. Subjective heat sensation during rest (left) and change in microclimate temperature (right). a: CON, b: TCG, c:CG

- There was a significant difference in microclimate temperature between CON/TCG (36.7 ± 0.4 , 36.2 ± 1.2 , respectively) and CG (29.7 ± 0.6) at the end of an experimental session (Fig.3).

- While T_{re} cooling effect was prominent in CG and no experimental trial was limited by T_{re} criteria in any condition, higher HR response was the main work limiting factor in CON and TCG (Fig.4).

Figure 4. Dynamics of T_{re} and HR responses of one subject under control and each cooling condition. The subject characteristics: a professional firefighter, age; 41yrs, height; 173cm, weight; 87.4kg, BMI; 29.2 kg/m²; VO_{2max} ; 34.3 ml/kg/min. Total exercise time (min) completed under each condition, excluding 2 min warm-up, was 26 (CON), 33 (TCG), and 45min (CG).



Conclusions

- In line with previous investigations, this study showed that exercise performed while wearing a firefighter ensemble incorporating an SCBA is physically very demanding and imposes high thermal stress, thus diminishing physical performance.
- Application of LCG appeared to help the recovery from strenuous physical activity and possibly prolongs performance time in subsequent bouts of activity.
- The results showed that cooling a greater body surface area better suppressed elevation of T_{re} . However, the optimal level of cooling to support strenuous activity is not conclusive in this study.

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